Journal of Sound and Vibration (1999) **228**(3), 701–702
Article No. jsvi.1999.2469, available online at http://www.idealibrary.com on IDEAL®

LETTERS TO THE EDITOR

COMMENTS ON "NON-STATIONARY RESPONSES OF A NON-LINEARLY COUPLED PITCH–ROLL SHIP MODEL UNDER MODULATED EXCITATION"

M. GHORASHI

Mechanical Engineering Department, Sharif University of Technology, P.O. Box 11365-9567, *Tehran, Iran*

(*Received* 20 *May* 1999)

1. INTRODUCTION

A simplified form for the set of differential equations describing the coupled non-linear pitch and roll motions of a ship has been discussed in reference [1]. For several cases, the resulting ship motions and the stability of these motions have been discussed. No experimental verification of the results has been presented. While the development is interesting, it seems that the set of differential equations which is adopted for the analyses is both oversimplified and incompatible with the physical nature of the problem. Hence, the results presented in reference [1] are questionable.

2. ANALYSIS

The set of differential equations for performing the analysis of coupled pitch and roll motions of a ship is as follows [2] (which is modified for the forced vibration case):

$$(I_{xx} + I_1)\,\ddot{u}_1 + V_1 u_1 + \boldsymbol{\mu}_1\,(\dot{u}_1 - u_1 u_2 \dot{u}_2) + V_2 u_1 u_2 - (I_{xz} + I_2 + I_8)\,\dot{u}_1\dot{u}_2 + I_7 u_1 \ddot{u}_2 + I_2 u_2 \ddot{u}_1 = F_1(t), \tag{1}$$

$$(I_{yy} + I_3)\,\ddot{u}_2 + V_3 u_2 + \boldsymbol{\mu}_2 \dot{u}_2\,(1 + u_1^2) + 0{\cdot}5 V_2 u_1^2 + 1{\cdot}5 V_4 u_2^2 + (I_{xz} + 0{\cdot}5 I_2 + I_7 + I_8)\,\dot{u}_1^2 + 0{\cdot}5 I_4 \dot{u}_2^2 + I_7 u_1 \ddot{u}_1 + I_4 u_2 \ddot{u}_2 = F_2(t), \tag{2}$$

where u_1 and u_2 are roll and pitch motions of the ship, respectively; and x, y and z stand for the longitudinal, transverse and vertical directions in the ship. The mass moments of inertia corresponding to these axes are shown by proper indices in equations (1) and (2). Other moments of inertia in the form of I_n denote the added inertia terms.

In reference [1], a simplified form of equations (1) and (2) has been considered for the case of modulated excitation as

$$\ddot{u}_1 + \omega_1^2 u_1 - u_1 u_2 + 2\varepsilon\boldsymbol{\mu}_1 \dot{u}_1 = 0, \tag{3}$$

$$\ddot{u}_2 + \omega_2^2 u_2 - u_1^2 + 2\varepsilon\boldsymbol{\mu}_2 \dot{u}_2 = (F_0 + F_1 \cos(\boldsymbol{\omega} t))\cos(\boldsymbol{\Omega} t). \tag{4}$$

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Such simplification has some shortcomings. Firstly, a comparison shows that the neglected terms in equations (3) and (4) are basically those related to the added inertia. However, in ship dynamics problems, the values of added mass and added inertia terms may be quite large and comparable with some similar parameters of the ship itself. Therefore, their cancellation may lead to substantial error in the results. Secondly, a comparison of the coefficients of the terms u_1u_2 and u_1^2 in equations (1) to (4) results in

$$\frac{V_2}{I_{xx}+I_1} = -1, \qquad \frac{0{\cdot}5\ V_2}{I_{yy}+I_3} = -1. \tag{5}$$

Regarding the ignorance of the added inertia terms in the above-mentioned analyses, one obtains

$$I_{xx} = 2I_{yy}. \tag{6}$$

Hence, for equations (3) and (4) to be valid, the mass moment of inertia about the longitudinal axis should be twice the mass moment of inertia about the transverse direction. It seems that this requirement is not satisfied in any existing kind of ship. In fact, the moment of inertia about the transverse direction is usually several times the corresponding one about the longitudinal direction.

The above discussion reveals that the adopted set of differential equations for performing the analysis is not accurate enough. Hence, as no experimental verification has been reported, the results presented in reference [1] seem to be controversial.

3. CONCLUSIONS

The adopted set of differential equations of motion in reference [1] is both oversimplified and unrealistic. The cancellation of added mass terms cannot be justified since these are not negligible when compared with the corresponding values of the ship itself. Furthermore, even if one ignores the effect of added mass terms, the set of equations of motion considered in reference [1] can be obtained only if the mass moment of inertia of the ship about its longitudinal axis is about twice of the corresponding value about the transverse axis. The occurrence of such a relationship is very unlikely in ships. Hence, the results in reference [1] which are based on such an over- and unrealistic simplification and are not verified by experimental outcomes are doubtful.

REFERENCES

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